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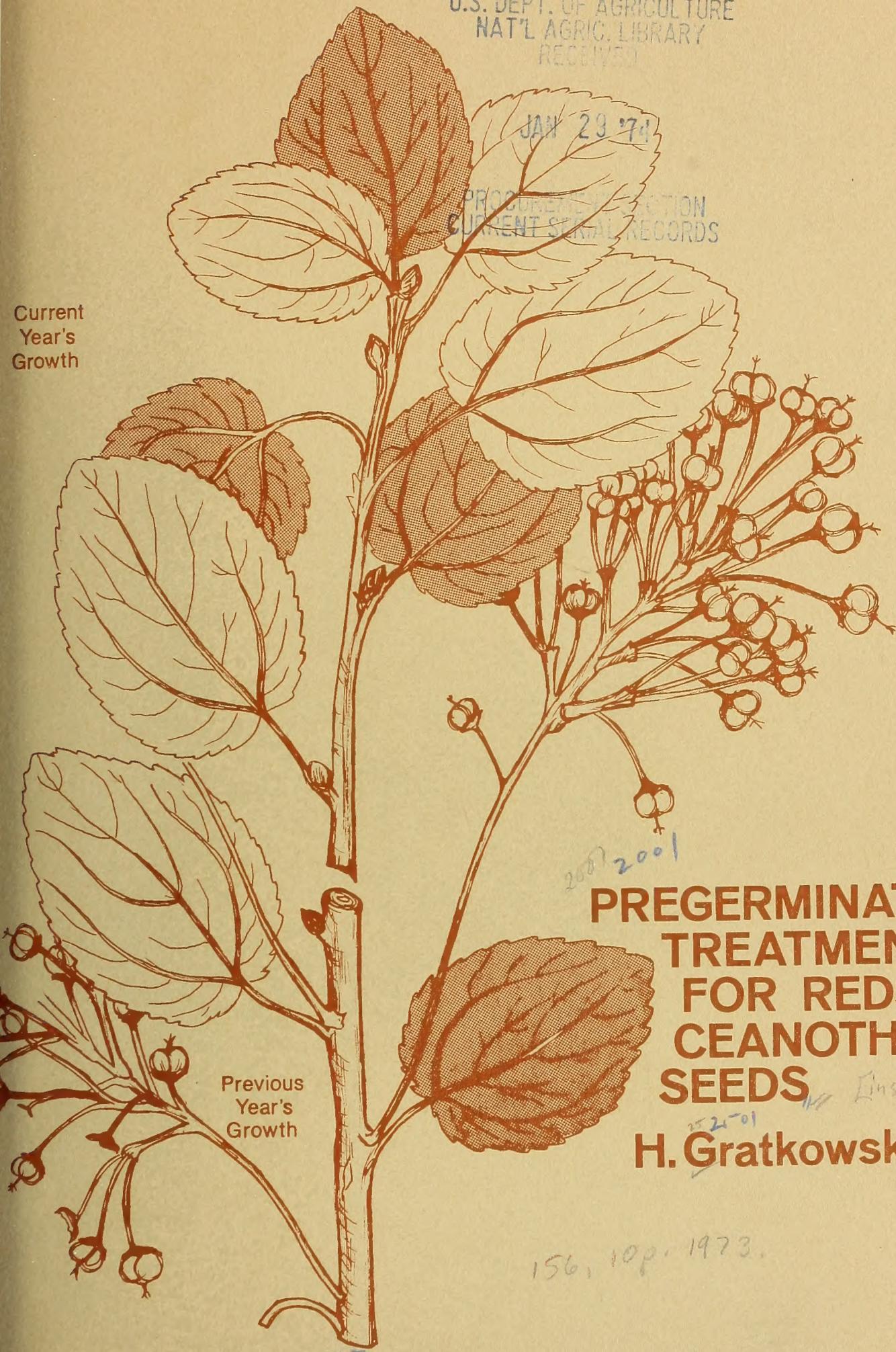
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PREGERMINATION TREATMENTS FOR REDSTEM CEANOOTHUS SEEDS

H. Gratkowski

2521-01 (Inside cover)

156, 10p. 1973.

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U.S.

Pacific Northwest Forest and Range Experiment Station. + 72-A
U.S. Department of Agriculture
Forest Service
Portland, Oregon

ABSTRACT

Redstem ceanothus seed coats can be made permeable to moisture by immersing the seeds in water preheated to 85° C. and allowing them to soak in the water until it cools to room temperature. After heat treatment, approximately 90 days' stratification is required to overcome embryo dormancy and allow after-ripening before germination.

In treating large amounts of seed for revegetation projects, it is recommended that the seed be heat-treated for 10 minutes at 85° C. and then sown immediately during the late fall rainy period, just before snowfall. They stratify naturally in the cold, wet soil during winter and germinate in spring.

Seeding new burns and cuttings in the vicinity prior to releasing trees on older cuttings will provide a continuous supply of low browse and allow use of the land for production of both timber and wildlife.

KEYWORDS: Redstem ceanothus, *Ceanothus sanguineus*,
seed dormancy, seed germination.

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Foresters and wildlife biologists have long been interested in seeding palatable native shrubs on forest and range lands and on winter range for big game. On forest land, shrubs ameliorate microclimatic conditions on harsh forest sites and increase survival of small trees (Wahlenberg 1930, Gratkowski 1967). In addition, some shrubs also provide excellent browse and cover for wildlife (Holmgren 1954, Brown and Martinsen 1959) and may reduce browsing of young trees.

Redstem ceanothus (*Ceanothus sanguineus* Pursh.) has often been considered for browse seeding. It has a range extending from northern California to British Columbia and eastward to western Montana. The erect deciduous shrubs are only 3 to 10 feet tall at maturity, and

their leaves and tender twigs are considered good forage for cattle, sheep, deer, and elk (Dayton 1931, Reid 1942, Leege 1969).

Initially, little was known about redstem ceanothus seeds and pregermination treatments to break their dormancy. Most redstem seeds, like those of other *Ceanothus* spp., evidently can remain dormant but viable in the soil for many years. Dormancy appears to be due to both impermeability of the seed coat to water and dormancy of the embryo. Before germination can occur, such seeds require heat or scarification to break the seed coat and allow the seed to imbibe moisture, followed by moist, cold stratification to allow after-ripening of the seed contents.

REVIEW OF LITERATURE

Hot water treatment followed by stratification is generally recommended to induce germination of most ceanothus seeds (Van Renssalaer and McMinn 1942). The usual treatment to overcome seed coat impermeability consists of immersing the seeds in hot water and allowing them to soak in the gradually cooling water until it cools to room temperature. Volume of water depends upon the amount of seed treated. One or 2 liters of water are sufficient for small lots of several hundred seeds.

Quick (1935) determined that initial water temperatures of 70° to 80° C. were most successful for breaking seed coat impermeability in 18 of 19 Californian species of *Ceanothus*. Such treatments resulted in more germination than that obtained by boiling the seeds for 1 minute or 5 minutes. Almost all species required stratification after the hot water treatment. Redstem ceanothus, however, was not among the species studied.

Peterson (1953) attempted to develop pregermination treatments for redstem ceanothus seeds, but seedling emergence was so low that the treatments must be termed unsuccessful. Some seeds were scarified by puncturing the seed coat with a dissecting needle. Others were given a hot water treatment by pouring 90 cc. of boiling water over seeds in a 100-cc. beaker and allowing them to soak in the cooling water for 30 minutes. Each treatment was followed by stratification for 90 days. The low emergence percentages indicate that scarification may have damaged the embryos and that initial heat loss in the small beakers may have reduced water temperature below the optimum required to overcome seed coat impermeability. Since the greatest emergence achieved was only 18 percent (scarified and stratified), no practical seed treatment was developed in Peterson's experiment.

MATERIALS

Seeds used in all three experiments were collected by W. C. Kivett^{1/} during 1964 at an elevation of 1,600 to 2,000 feet above sea level in the Cascade Range approximately 50 miles east of Eugene, Oregon. In this area, most *Ceanothus* seeds ripen during August and early September. From October 1964 until used

in experiments, the cleaned seeds were stored in dry paper containers at 3° C. Pregermination treatments were based upon the author's intensive research on germination of *Ceanothus* seeds from 1957 to 1965 (continuing to the present time) and upon earlier work by Wright (1931), Sampson (1944), and Quick (1935 and 1961).

EXPERIMENTS

This research paper reports results of three experiments in germination of redstem *Ceanothus* seeds. They include: (1) effect of hot water treatment to break seed coat impermeability, (2) effect of high soil temperatures on germination of redstem *Ceanothus* seeds, and (3) effect of cold storage on viability of redstem seeds.

HOT WATER TREATMENT

Despite Peterson's results, Quick's experiments and the author's experience with other *Ceanothus* seeds indicated that hot water treatment followed by stratification should be an easy and effective way to induce germination of redstem *Ceanothus* seeds.

One-hundred-seed samples of redstem *Ceanothus* seeds were heat treated on January 12, 1965, by immersing them in 1-liter flasks of hot water and allowing them to soak until the water cooled to room temperature. Initial water temperatures ranged from 75° C. to 100° C. After heat treatment, the seeds were stratified between moist blotters in petri dishes at 3° C. for 4 months and then germinated on moist, sterilized blotters in covered petri dishes.

Germination of the redstem seeds after hot water treatment and stratification was similar to that of seeds of most *Ceanothus* species. A few seeds--usually 5 percent or less--in most collections have permeable seed coats and require only stratification before germination. Since only a small percentage are naturally permeable, the 75° C. hot water treatment obviously produced a major increase in germination. However, the optimum initial water temperature for breaking seed coat impermeability was 80° to 90° C. (table 1).

HEAT-INDUCED GERMINATION OF SEEDS IN SOIL

Although studies have shown that heating in ovens or immersion in hot water will induce germination of *Ceanothus* seeds, almost nothing was known about the effect of heat on *Ceanothus* seeds buried in forest soil. Despite this, observation of *Ceanothus* seedlings in new burns repeatedly led investigators to speculate that fire stimulates germination of dormant seeds in the soil (Brandegee 1894, Quick 1959, Gratkowski 1961). This would explain the origin of dense stands of *Ceanothus* that quickly occupy new burns and forest cuttings after slash burning.

^{1/} Wildlife Biologist, Blue River District, Willamette National Forest.

Results of a laboratory-greenhouse study indicated that germination of redstem

Table 1.--Germination of redstem ceanothus seeds after immersion in hot water to break seed coat impermeability

Initial water temperature (°C.)	Seeds per sample	Germination		
		Number of seeds	Average number	Percentage
75	100	64	64	64
80	100	90	90	90
85	100	79	79	79
90	100	89		
90	100	56		
90	100	80	78	78
90	100	86		
90	100	79		
95	100	46	(1/)	(1/)

1/ Germination count incomplete. Mold started in permeable seeds.

seeds in soil is induced when the soil is heated by wildfires or logging slash fires.

Replicates of 50 seeds each were buried for periods of 4, 13, 22, 31, or 40 minutes in fine, dry sand preheated to soil temperatures of 30°, 45°, 60°, 75°, 90°, 105°, 120°, or 135° C. Each treatment was replicated four times in a 5 x 8 factorial experiment in a randomized block design. Thermocouples and a recording potentiometer were used to control soil temperatures during treatment. All seeds were stratified in moist vermiculite at 3° C. for 3 months after heat treatment.

Soil temperatures of 60° C. or less did not cause the seeds to germinate (fig. 1). A few seeds germinated after exposure to 75° C. soil temperature, but maximum germination was obtained from seeds exposed to soil temperatures of 105° C. At 120° C., soil temperatures reached the lethal level. Germination decreased with increasing duration of exposure in soil heated to 120° C., and even 4 minutes in soil heated to 135° C. killed all redstem ceanothus seeds of this seed lot.

Although the seed coats became permeable to moisture within 4 minutes

at soil temperatures up to and including 105° C., continued exposure for as long as 40 minutes did not reduce viability of the permeable seeds. This ability to withstand high soil temperatures for at least 40 minutes is an important survival mechanism. It allows redstem ceanothus seeds to endure such soil temperatures during wildfires and logging slash fires and then germinate and occupy the burned areas.

Soil temperatures within the range that will induce germination of redstem ceanothus seeds are produced under burning logging slash in cuttings. Burning light slash or small accumulations of logging slash is most apt to produce soil temperatures that will induce germination. Greater amounts of slash will raise soil temperatures to lethal levels at depths from which redstem seedlings can emerge after germination. Similar effects undoubtedly occur during wildfires.

In the Pacific Northwest, most wildfires occur during late summer and early fall, and logging slash is burned shortly after the fall rains begin. Seeds made permeable by the fires imbibe moisture from the moist soils, stratify in the cold, wet soil during the winter, and germinate the following spring.

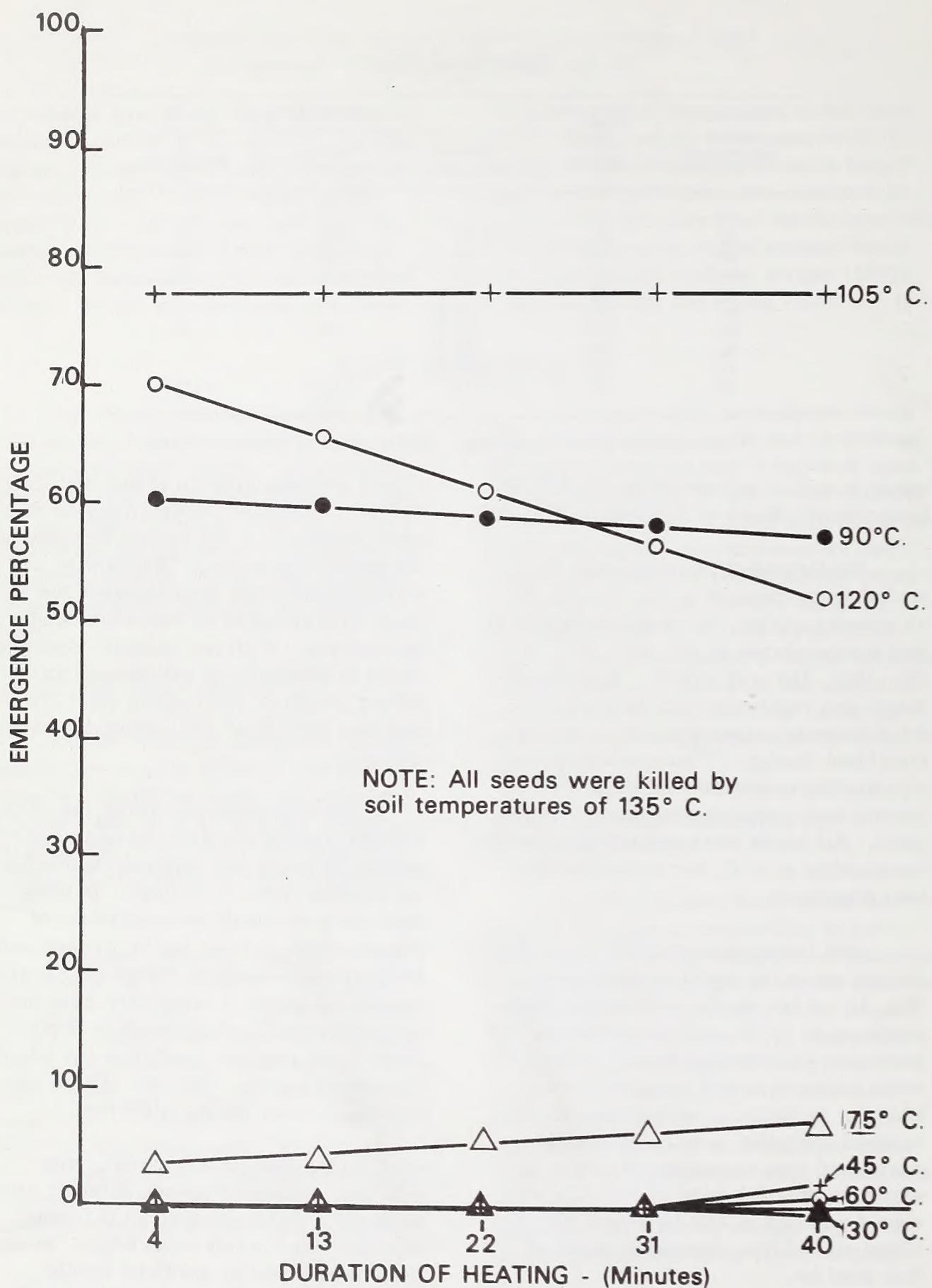


Figure 1.--Emergence of redstem ceanothus seeds heated in dry sand at soil temperatures ranging from 30° to 120° C. for various lengths of time.

VIABILITY IN COLD STORAGE

Large amounts of brush seed are not generally available from seed dealers. Where large amounts of *Ceanothus* seeds are required for revegetation projects, they are usually collected from native shrubs and stored until needed. Since seeds of most native shrubs ripen during late summer and early fall during the peak of the fire season and slash burning, personnel may not be available to collect seed. Seed must often be collected during years when men are available and stored until needed. Proper storage conditions for retention of viability are, therefore, an important consideration.

Ceanothus seeds appear to be long-lived and do not seem to require special storage conditions. Quick and Quick (1961) conducted germination tests of 12 species of *Ceanothus* seeds that had been in storage from 9 to more than 24 years. Germination of 18 of the 22 seed lots represented exceeded 80 percent--indicating that there was little loss of viability during the long periods in storage.

Redstem *Ceanothus* seeds used in the experiments described in this paper were stored in dry paper containers in

a refrigerator at 3° C. One year after the high soil temperature experiment, samples of the same seed lot were tested to determine whether there was any loss of viability during the additional year in storage.

Pregermination heat treatments and stratification were the same as in the earlier experiment, but only selected treatments were duplicated. Four replicates of 50 seeds each were buried for 22 minutes in fine sand preheated to soil temperatures of 45°, 75°, 90°, and 120° C. The 90° C. treatment was duplicated for all five durations of exposure--4, 13, 22, 31, and 40 minutes. After heat treatment, the seeds were stratified in moist vermiculite for 3 months at 3° C.

No discernible loss of viability occurred during the additional year in dry cold storage (table 2). Differences in seedling emergence are simply the result of biological variation in percentage of viable seeds among the 50-seed samples. They do not indicate any increase or loss of viability in storage. Storage in dry paper containers at 3° C. in an ordinary refrigerator seems an easy and practical method for storing redstem *Ceanothus* seeds.

Table 2.--Germination of redstem seeds after 5 months (1965) and 17 months (1966) in cold, dry storage at 3° C.

Soil temperature (°C.)	Duration of heating	Seedling emergence ^{1/}		Change in viability
		1965	1966	
	-----Minutes-----		-----Percent-----	
45	22	0.5	0	-0.5
75	22	7.5	15.0	+7.5
90	4	58.5	68.5	+10.0
90	13	59.5	57.0	-2.5
90	22	65.0	54.5	-10.5
90	31	54.0	67.5	+13.5
90	40	58.0	67.0	+9.0
120	22	54.0	44.5	-9.5

^{1/} All percentages are averages for four replicates of 50 seeds each.

SEED COLLECTION

In the Cascade Range east of Eugene, Oregon, redstem ceanothus seed (fig. 2) usually ripens and is disseminated between August 10 and August 30.^{2/} In other areas, however, maturation will vary somewhat depending upon elevation and climatic conditions.



Figure 2.--Macrophoto of redstem ceanothus seed.

A good time to gather seeds is just as the first capsules break open or shortly before that occurs. As fruit and seeds mature, the exterior pulp dries, blackens, and partially flakes off exposing the capsules. The capsules then become dry and brittle, snap open, and the seeds pop out. Cutting tests should be used to determine time for earlier collection. Filled, viable redstem seeds turn dark

brown as they mature; light colored seeds are usually unfilled or insect infested. A cutting test as the fruit pulp dries will show when seeds are mature and seed collection can begin.

Ripe capsules are easily stripped by hand from the flower stalks. Stripping is much less expensive (about \$8.26 per pound of clean seed) than bagging ripening fruits (approximately \$32.50 per pound).^{3/} Capsules should be cracked and broken gently to prevent damage to the seeds. The Seed Laboratory at Oregon State University recommends a belt thrasher with two continuous belts, one moving nine times faster than the other in the same direction.^{3/} If the cracked capsules are then stored in dry covered containers at 70° to 80° F. for several days, most of the cracked capsules will open. The seed is then easily extracted with a Clipper seed cleaner.

Some lots of ceanothus seed contain many seeds infested by insects that appear to be seed chalcids. Before emerging, their presence is sometimes detectable by a light-colored area on the dark surface of the seed where the chalcid has consumed the endosperm and the collapsed cells containing pigments that give the seeds their characteristic color. If the insects have matured and emerged, a small hole in the seed coat is evidence that the seed should be rejected.

^{2/} Communication from Edmund Harshmann, Wildlife Biologist, Willamette National Forest, Eugene, Oregon.

^{3/} See footnote 2.

DISCUSSION

Results of the soil temperature experiment clearly show that wildfires and logging slash fires will induce germination of dormant redstem ceanothus seeds in forest soils. Hypocotyls (stems) of most newly germinated *Ceanothus* seedlings are only 1 to 2 inches long. Therefore, soil temperatures that will induce germination must be produced within this depth below the surface if redstem cotyledons (seed leaves) are to emerge above the soil surface and the seedlings are to survive. Such temperatures occur at this depth during wildfires, burning of light logging slash, and prescribed burning of chemically desiccated brushfields (Gratkowski 1964, Gratkowski and Philbrick 1965).

Leege (1968) studied prescribed burning of brushfields to increase browse on big game winter range in northern Idaho. He reported that fall burns produced approximately 240,000 redstem seedlings per acre; spring burns produced only 60,000 seedlings per acre. Fall burns were probably more effective in heating the relatively dry soil than spring burns on wet soil. Also, fall fires break seed coats of ceanothus seeds in the soil just before cold, wet winter weather provides natural conditions for stratification and after-ripening. The seeds germinate during warm weather the following spring (Gratkowski 1962, Leege 1969).

Response of redstem ceanothus seeds to heat treatment is similar to that of other ceanothus seeds. Immersing small lots of seed in hot water and allowing them to soak until the water cools to room temperature is an easy and effective method to render seed coats permeable for experiments, tests of viability, or production of small numbers of seedlings in nurseries. When seeds

are withdrawn from the water, they should immediately be stratified to prevent loss of moisture from the seed contents and to allow after-ripening of the embryos. Experience with redstem seeds in these experiments and with seeds of other *Ceanothus* species in earlier work indicates that 90 days' stratification should be sufficient for most redstem seeds.

In revegetation projects, where large amounts of seed must be treated, a different technique would be advisable. Ten or 20 gallons of water can be pre-heated to about 85° C. in a large pot or tub, and seed can probably be effectively treated at a rate of 1 pound of seed per gallon of water. It is important that the volume of water be sufficient to prevent cooling when the seed and its container are immersed and that temperature of the water be maintained at about 85° C. throughout treatment. A large, flat-bottomed basket of 20-mesh wire screening with a handle can be used to immerse and move seeds during treatment. Movement should cause the water to flow between the seeds to insure efficient transfer of heat to the seed coats during treatment. Vertical motion will probably be more effective than rotation of the basket. Immersion for 5 to 10 minutes should be sufficient to make the seed coats permeable.

Artificial stratification may not be advisable in project-scale seeding of redstem ceanothus. Stratification requirements of ceanothus seeds vary considerably among species; some species do not require stratification (USDA Forest Service 1948). Required duration of stratification varies even among different collections of seeds of the same species (Quick and Quick 1961), and this probably applies to different collections of redstem seeds. Therefore, redstem

seeds that require only a short period of stratification may begin germinating before they are removed for sowing. Extruded radicles (roots) on these seeds will be damaged or broken during the seeding process, and seedling numbers may be drastically reduced.

Instead, it is easier and safer to sow the seeds immediately after heat treatment in late fall and allow the seeds to stratify naturally in the cold, wet soil during the winter months.^{4/} Sowing should be done just before snow falls, after fall rains have thoroughly wet the soil. If sown during the late fall rains, the small seeds can fall into crevices in the soil and be covered by soil washed in by rain and melting snow. Snow falling soon afterward will cover the seeds and minimize losses to birds and rodents.

Where soil moisture is sufficient for both trees and shrubs, foresters and wildlife biologists probably can safely introduce redstem ceanothus on new burns and cuttings to serve as a nurse crop for young trees and provide browse for game animals. Once the trees are well established, however, redstem ceanothus and other shrubs should be controlled to reduce competition and provide increased

^{4/} The author has recommended this method to foresters and wildlife biologists for more than 10 years.

light and soil moisture for best growth of the trees. Safe and inexpensive methods involving aerial application of herbicides have been developed (Gratkowski 1961b, 1965) to release Douglas-firs and ponderosa pines from deerbrush and redstem ceanothus without damaging the trees. Prior seeding of other new burns and cuttings in the vicinity can provide new browse to replace that eliminated in releasing the conifers and allow use of the land for production of both timber and wildlife.

Finally, a brief explanation seems desirable for those who may be troubled by the difference in soil and water temperatures that induced maximum germination of redstem seeds in these experiments. To induce germination of ceanothus seeds, soil temperatures must be higher than effective temperatures of hot water. This relationship is due to differences in both heat capacity (calories of heat per unit volume) and efficiency of heat transfer. Water not only has a higher heat capacity; it is also much more efficient in transferring heat to the seed surface because of its greater density and much better contact with the seed surface. In these experiments, for example, maximum germination was achieved with initial water temperatures of 80° to 90° C. In contrast, a soil temperature of 105° C. was needed to attain maximum germination of seeds from the same seed lot.

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Redstem ceanothus seeds have both impermeable seed coats and dormant embryos that prevent germination. Dormancy can be broken by 10 minutes immersion in water heated to 85° C. followed by cold, moist stratification at 3° C. for 3 months. For project-scale seeding, seeds can be heat-treated and sown immediately during late fall rains just before snowfall. The seeds will stratify naturally in the soil during winter and germinate the next spring.

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